SVARTISEN T2: INVESTIGATION AIMED TO FIND THE ROOT CAUSE OF A FAILURE.

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VPdiagnose *VÄSTERÅS SWEDEN*

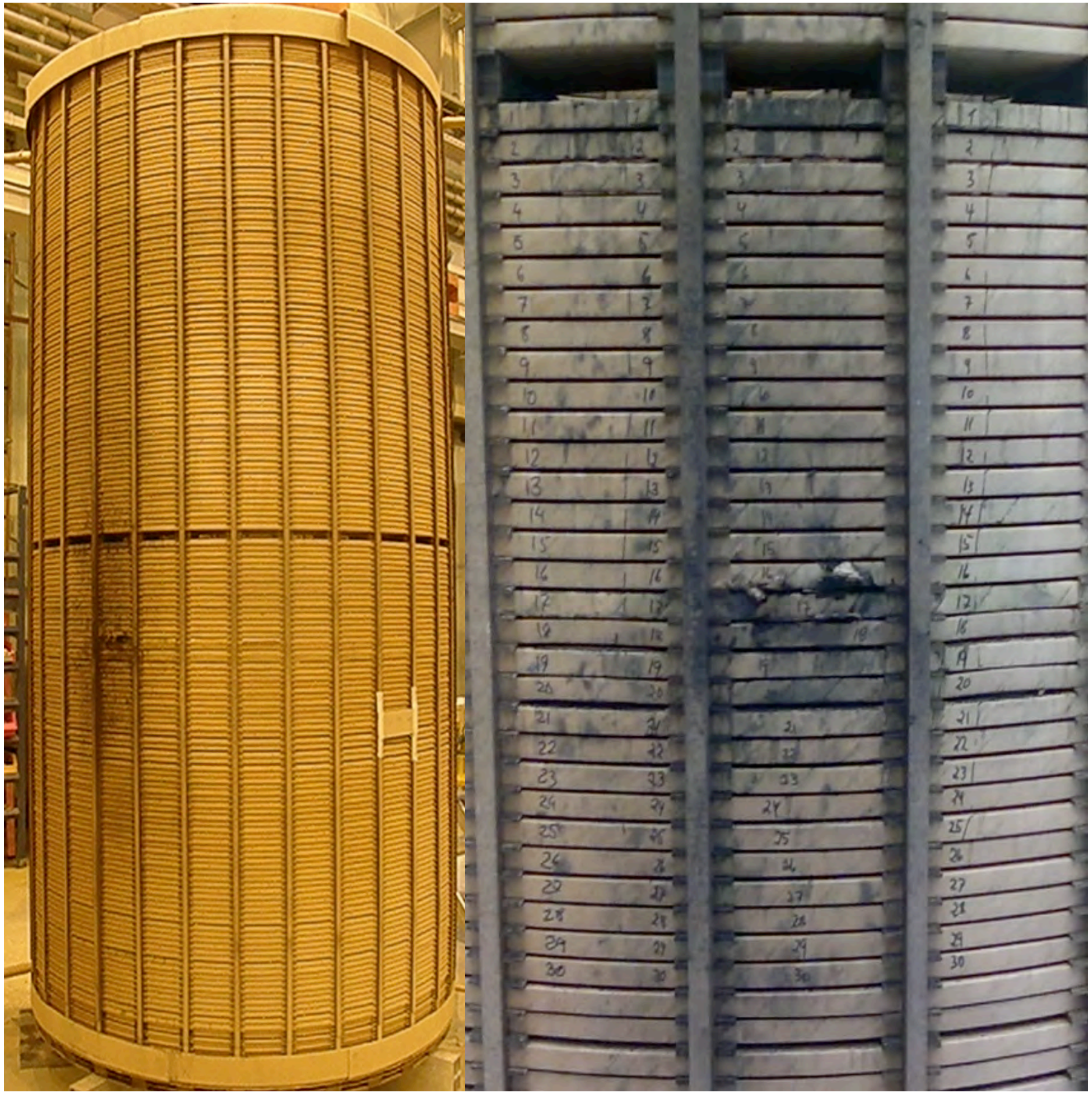
LOCATION OF THE FAILURE ?

A ***LOCAL WEAKNESS*** in the SOLID dielectric insulation in combination with high electrical stress i.e. the point of

CELLULOSE DI-ELECTRIC STRENGTH COLLAPSE

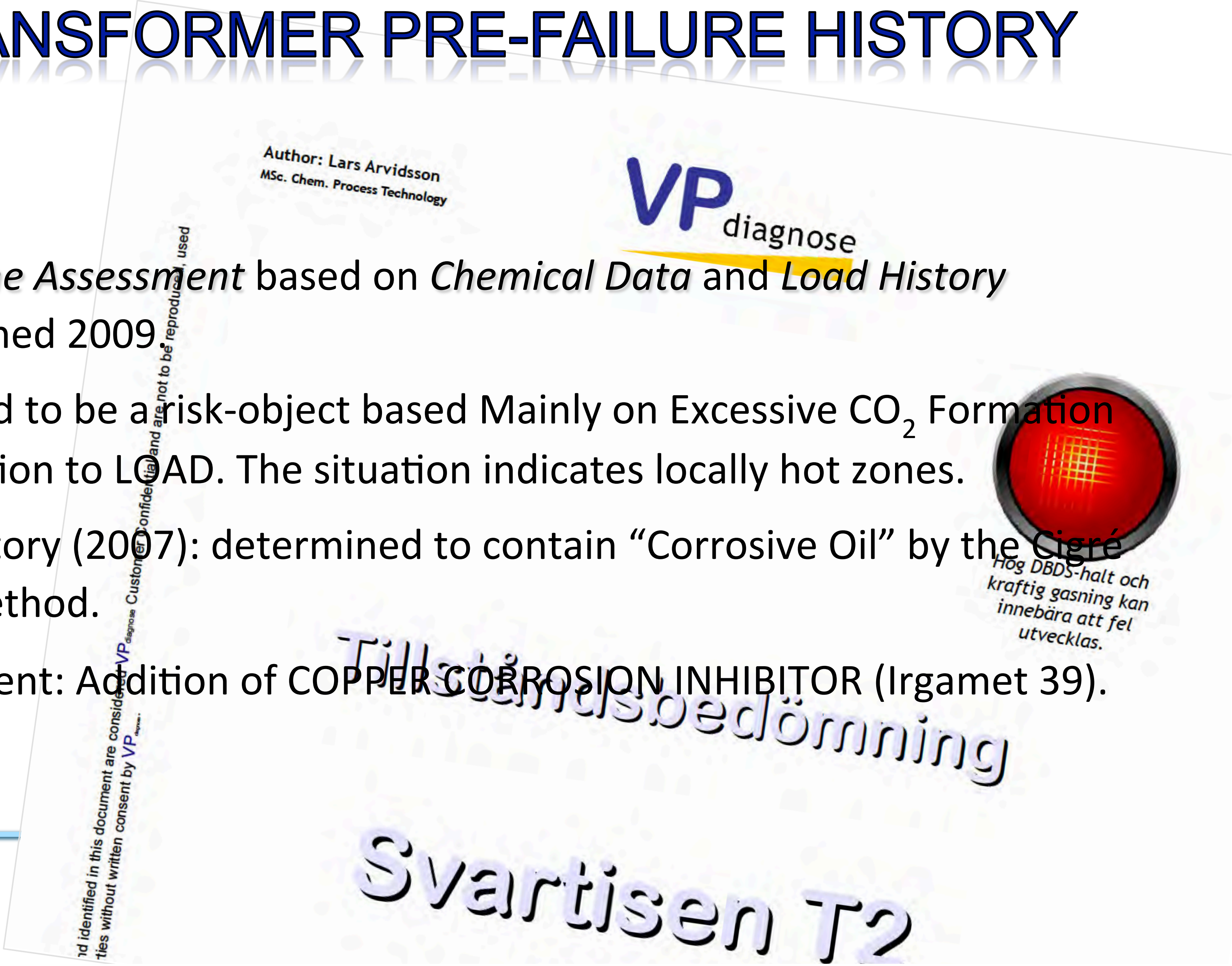
FAULT LOCATION

- Lower part of A-phase.
- Each section had approx. 55 disks each with 40 windings from outer side towards the core.
- Disks 16, 17 and 18 from ”waist” and down was the flash-over ”centre”.



TRANSFORMER PRE-FAILURE HISTORY

- *Life Time Assessment* based on *Chemical Data* and *Load History* performed 2009.
- Deemed to be a risk-object based Mainly on Excessive CO_2 Formation in Relation to LOAD. The situation indicates locally hot zones.
- Pre-history (2007): determined to contain “Corrosive Oil” by the Cigré CCD method.
- Treatment: Addition of COPPER CORROSION INHIBITOR (Irgamet 39).



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Hög DBDS-halt och kraftig gasning kan innebära att fel utvecklas.

Tillståndsbedömning

Svartisen T2

FAULT TYPE.

- *DGA* suggested flash-over due to *ARC*. (H_2 and C_2H_2)
- Electrical measurements verified flash-over winding-turn to winding-turn.
- Fault Type = typical for “CORROSIVE SULFUR” failure.
- No PUBLISHED failure investigations reports found, that report ROOT cause for this type of failure.

WHAT IS THE ”ROOT CAUSE”?

- Flash-over is the Root Cause?

  No!

- Di-electric medium collapse causing the Flash-over. Is that ROOT cause?

  No!

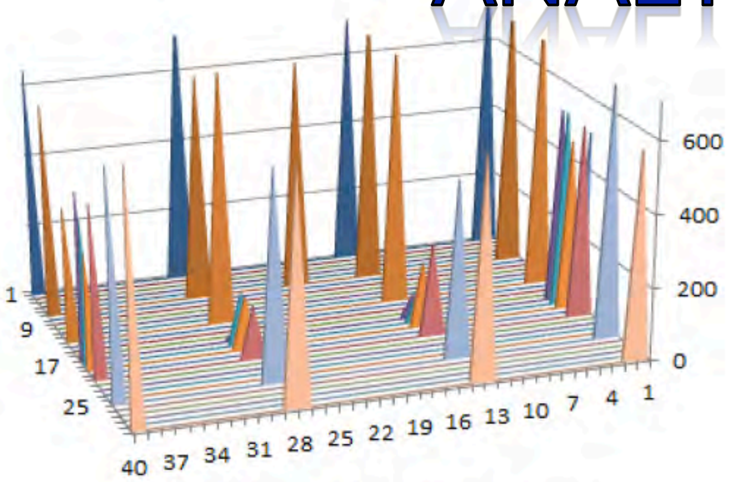
- *What Causes the* LOCAL *Di-electric Medium collapse is the ROOT CAUSE*!!!

INVESTIGATION DEFINITION.

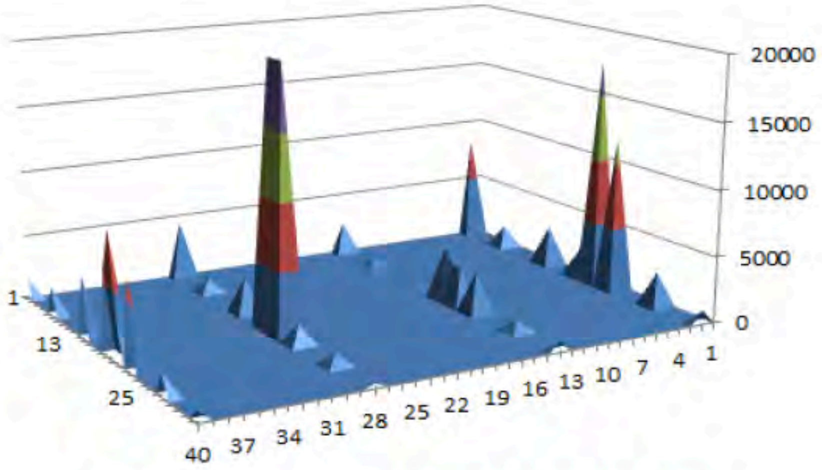
Di-Electric Media Oriented.

- Di-electrical Parameter: tan δ. *80 samples of..*
- Chemical Parameters: Copper, Sulphur etc (24 elements) *80 of..*
- Mechanical Parameters: Tensile Strength. *240 of ...*
- Physical Parameter: Degree of Polymerization. *80 of ….*

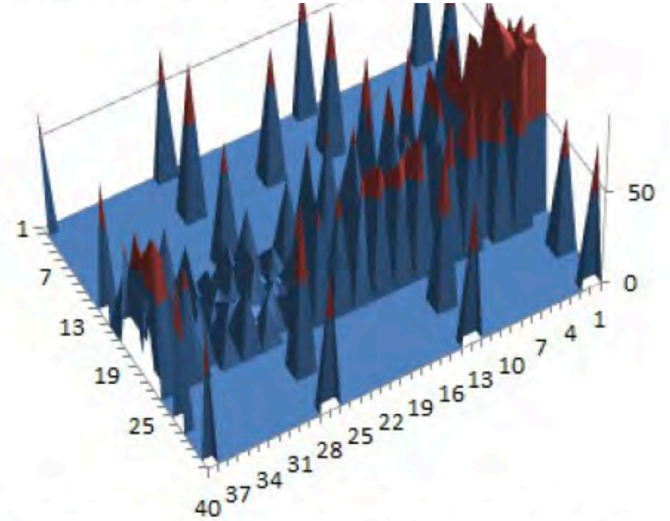
ANALYTICAL RESULTS



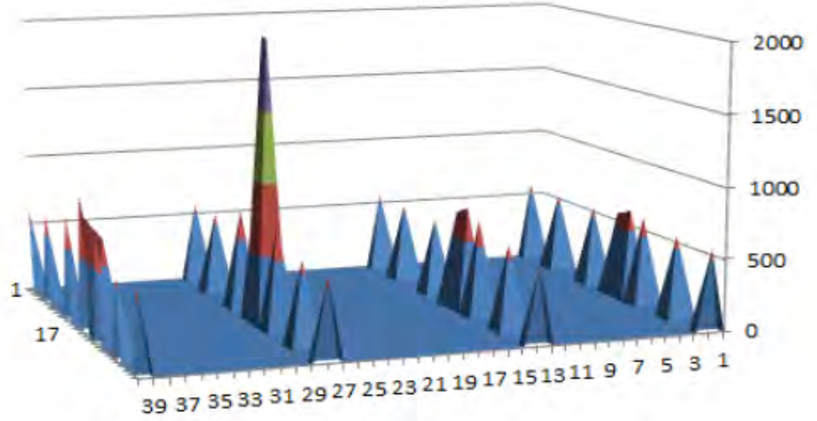
DP vs axial and lateral sample location.



Copper contents vs axial and lateral sample location



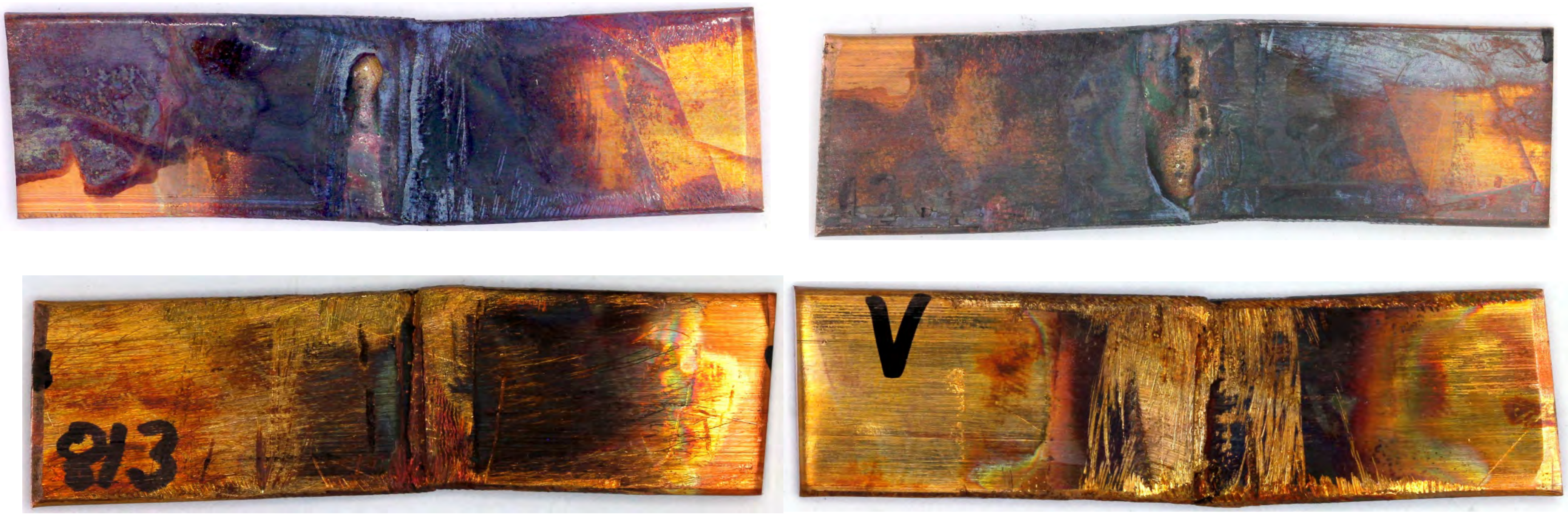
Tensile Strength vs axial and lateral sample location.



Sulphur content in Cellulose (mg/kg, ppm)

WHY LOCALLY EXCEPTIONAL COPPER CONTENTS?

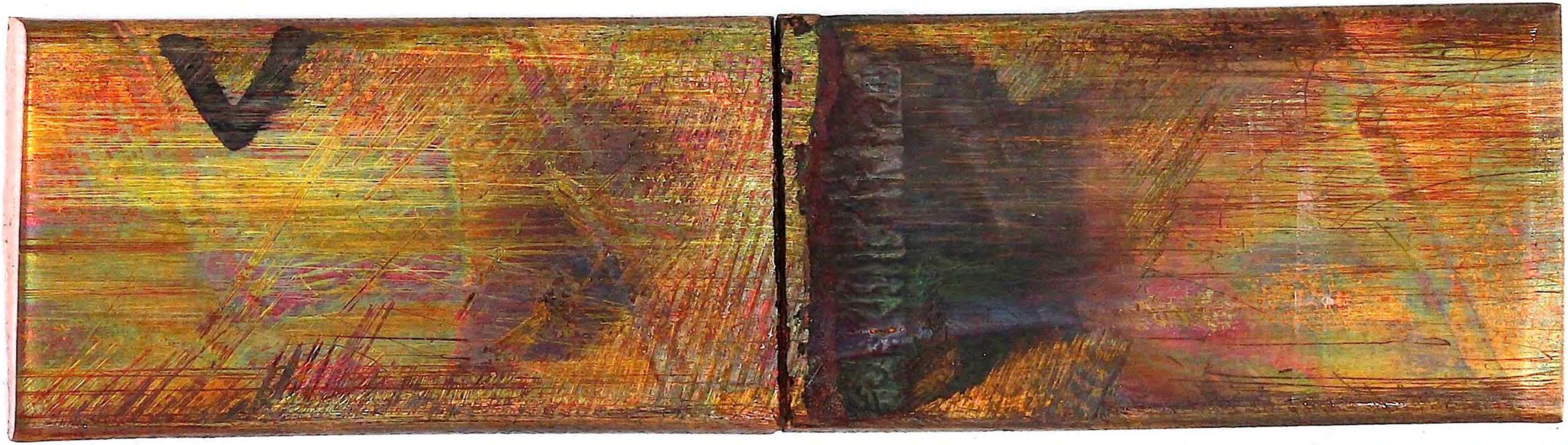
Joints! Butt Welds (+soldered joints)



57 JOINTS FOUND IN THE FAULT SECTION

◆ Quality level from *”bad”* to *”unspeakable”*.

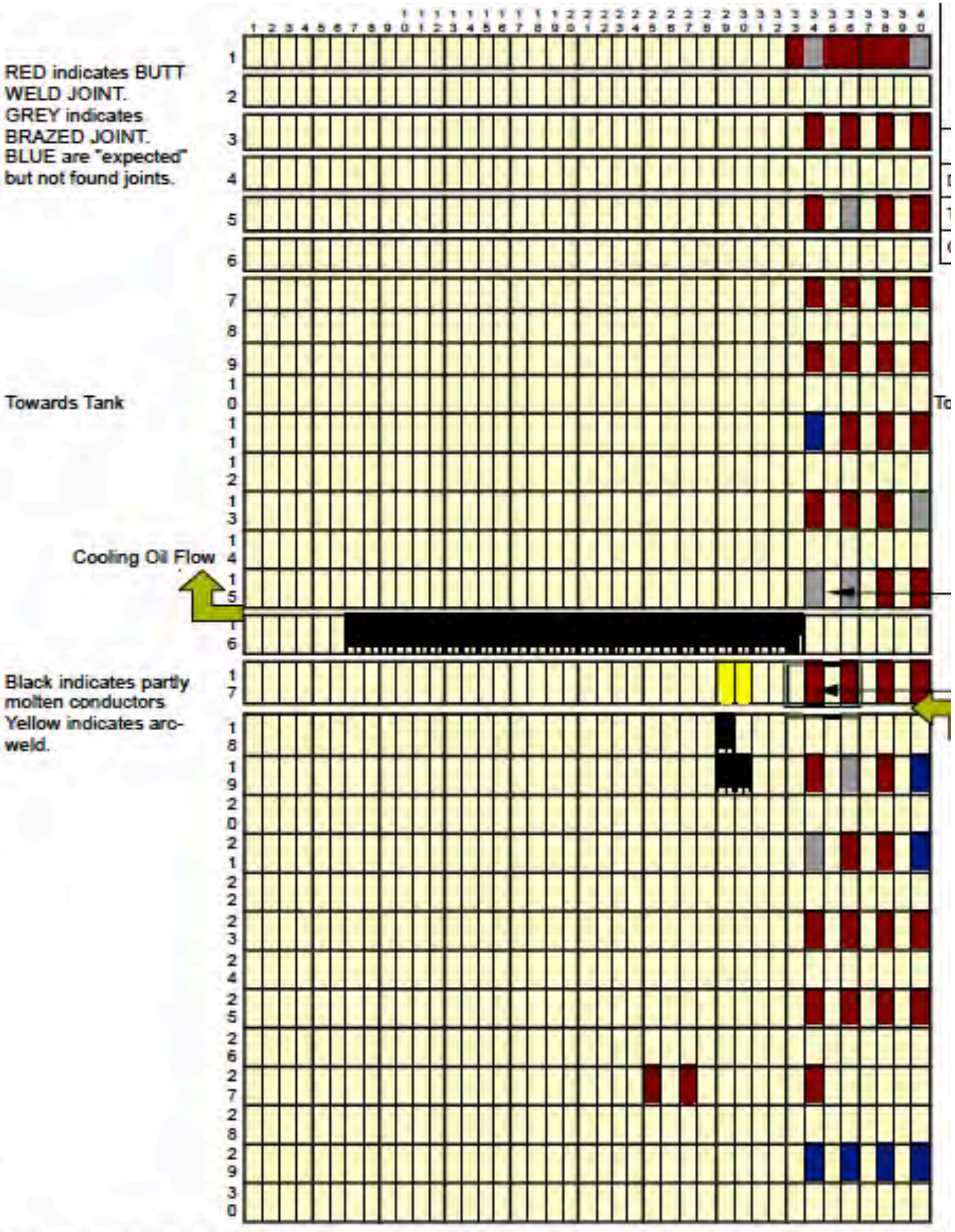
◆ THIS even fell apart when the cellulose was removed.



FAULT LOCATION

Detailed investigation revealed:

ALL JOINTS had **EXCESSIVE COPPER CONTENT** in surrounding CELLULOSE



RED indicates BUTT WELD JOINT. GREY indicates BRAZED JOINT. BLUE are "expected" but not found joints.

Black indicates partly molten conductors Yellow indicates arc-weld.

Side view of the section where failure occurred. Right is towards LV and core and LEFT is towar

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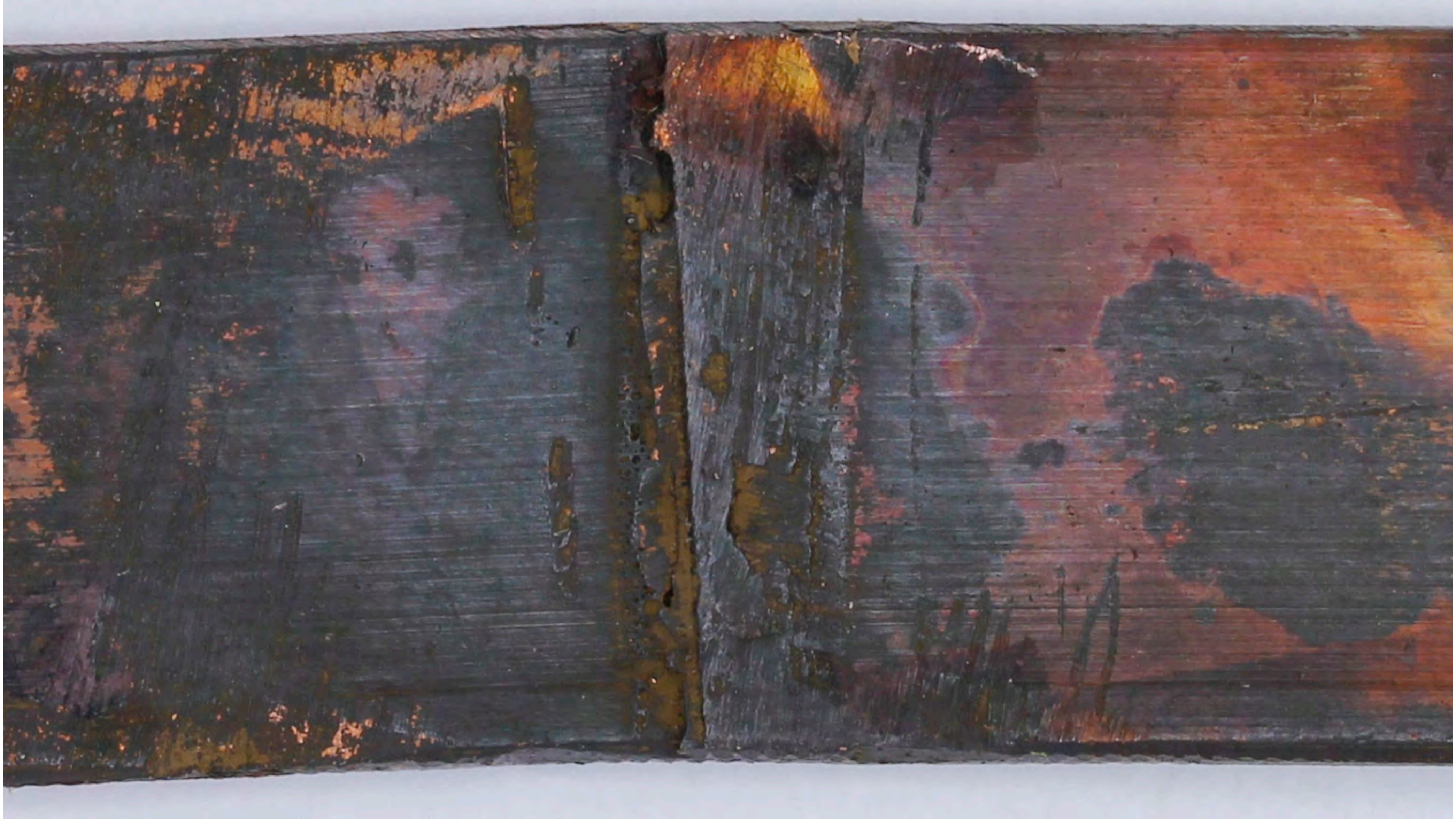
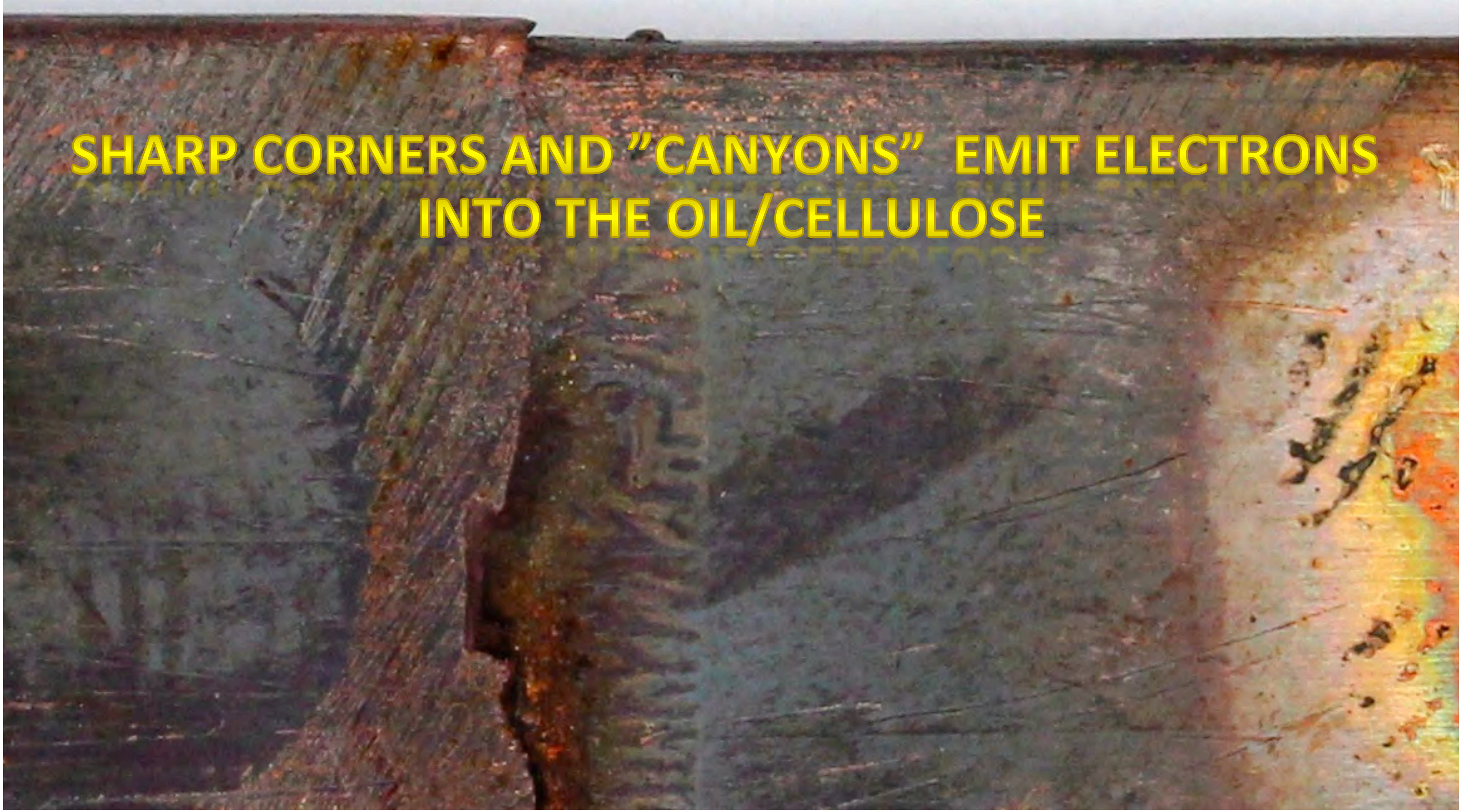
DEEPER INVESTIGATION OF JOINTS.

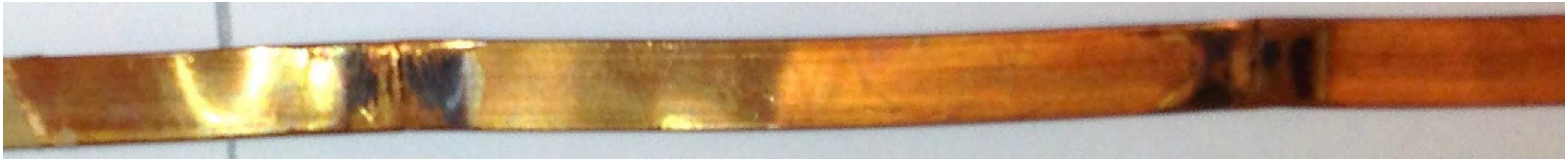
Di-Electric Media Surrounding the Joint

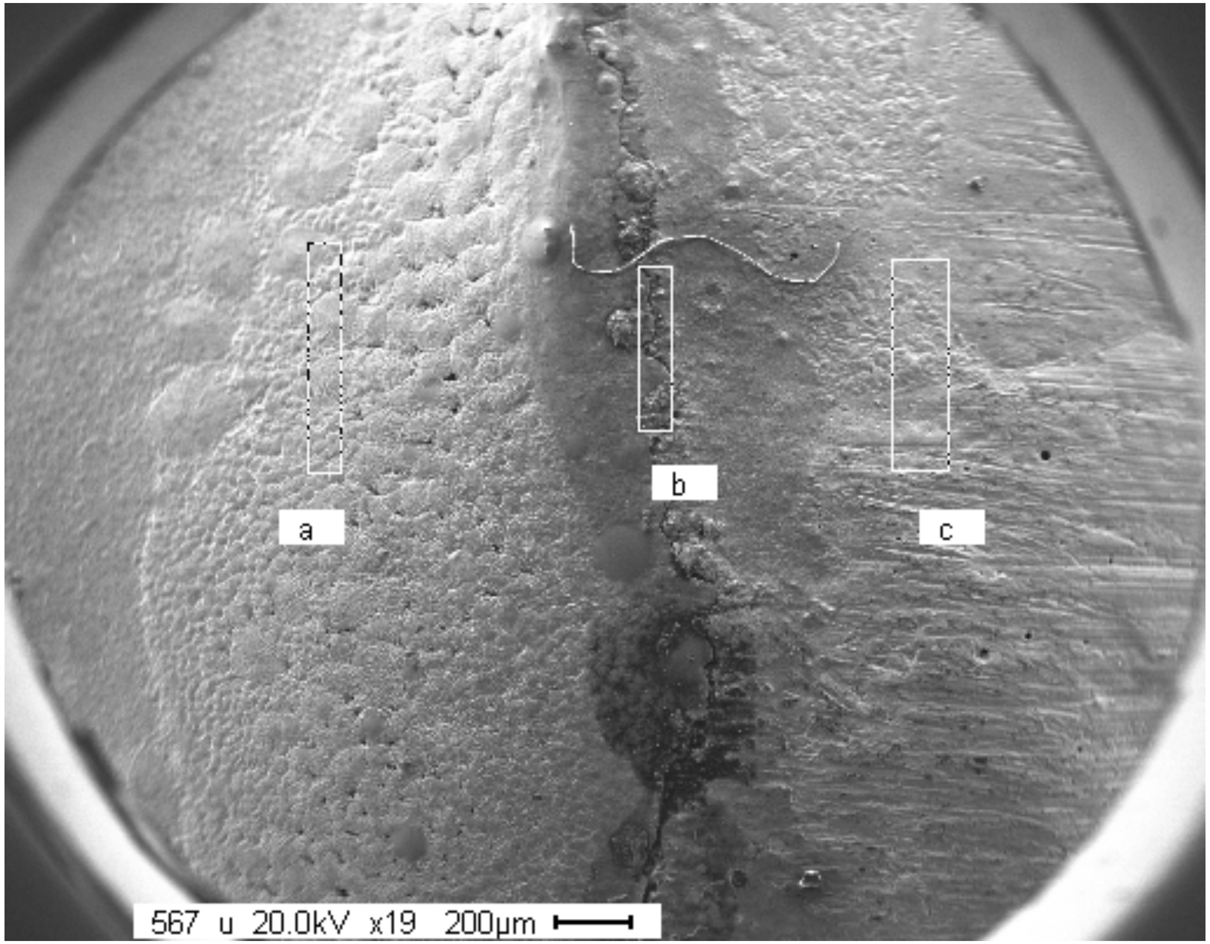
- Di-electrical Parameter: tan δ. *57 samples of..*
- Chemical Parameters: Copper, Sulphur etc (24 elements): *57 of..*
- Optical Microscope Inspection: *57 samples of …..*
- Photographic Documentation: *57 samples.....*
- Scanning Electron Microscope: *57 samples of …..*
- GD-OES (Glow Discharge Optical Emission Spectroscopy): *5 of....*
- **Full Failure Investigation report: limited to 90 pages due to excessive data amount.**

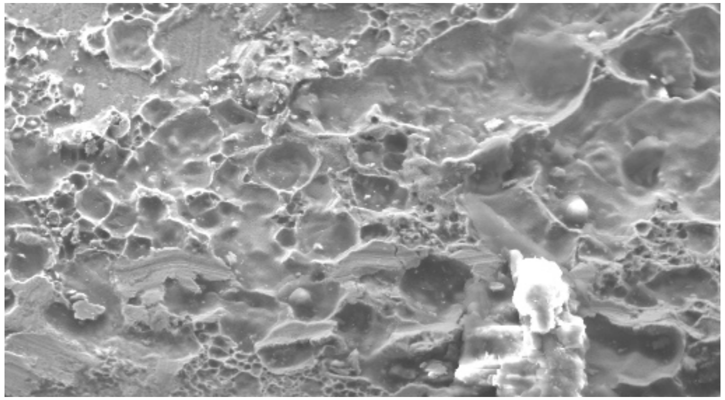


SHARP CORNERS AND ”CANYONS” EMIT ELECTRONS INTO THE OIL/CELLULOSE





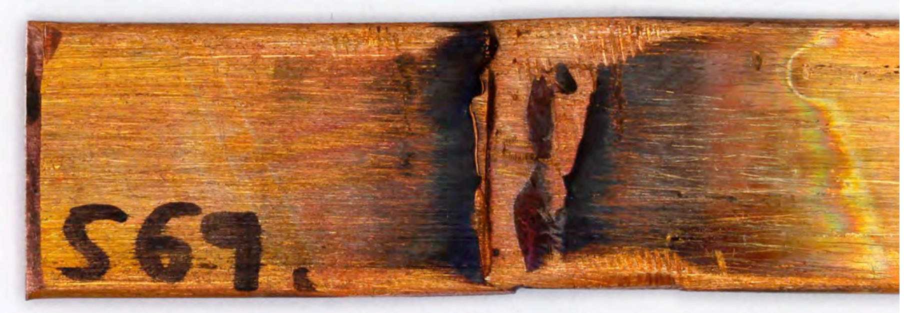

b
a
c
567 u 20.0kV x19 200µm

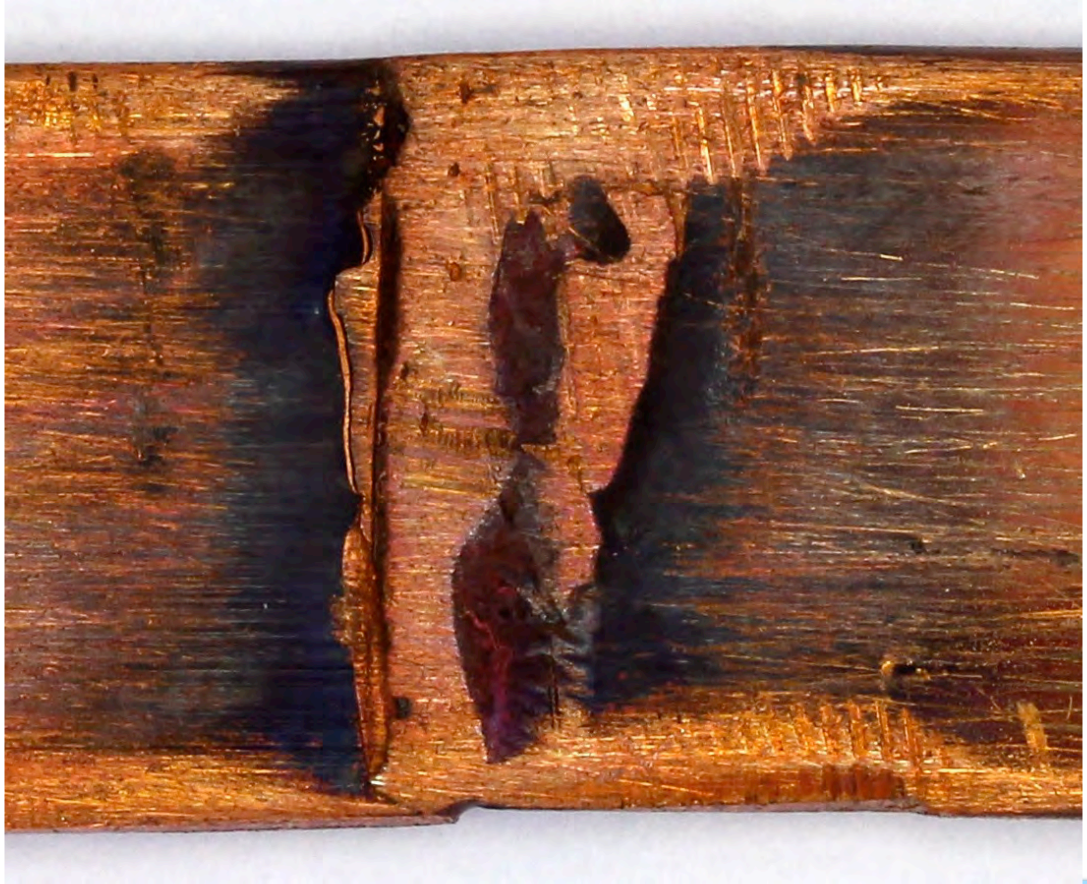


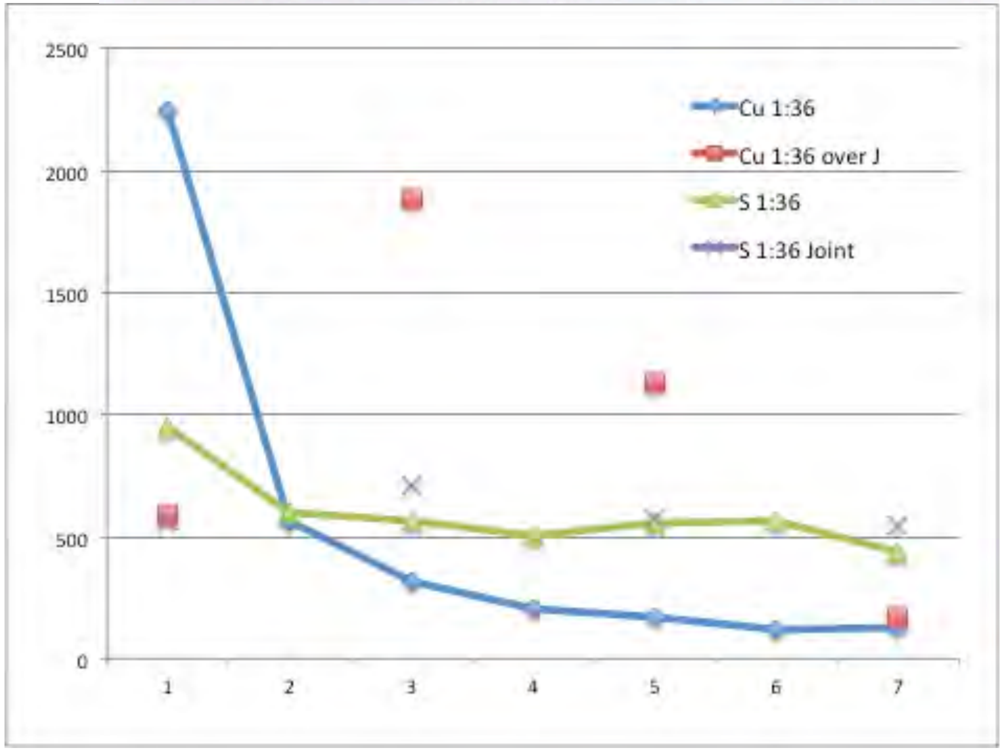
CELLULOSE INVESTIGATION. LAYER BY LAYER…

Cu, S and 20 other Elements Concentration Gradients were determined over joint and 15-20 cm beside joint, (for reference).

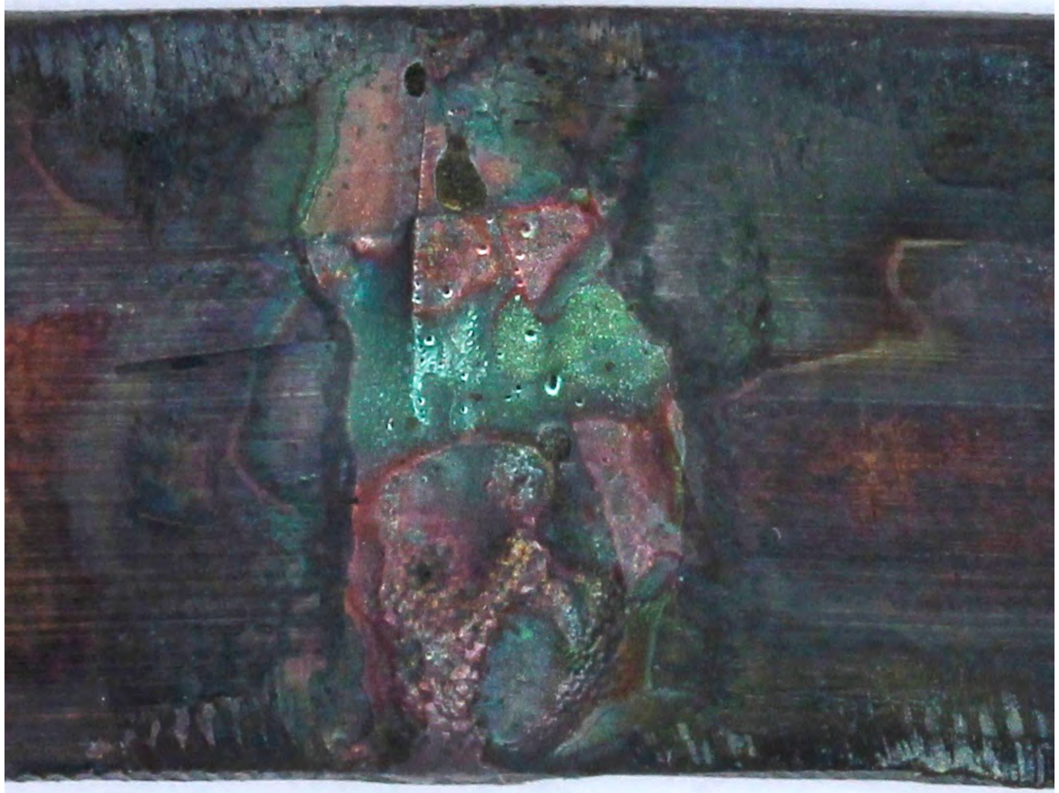
CELLULOSE INVESTIGATION. LAYER BY LAYER…

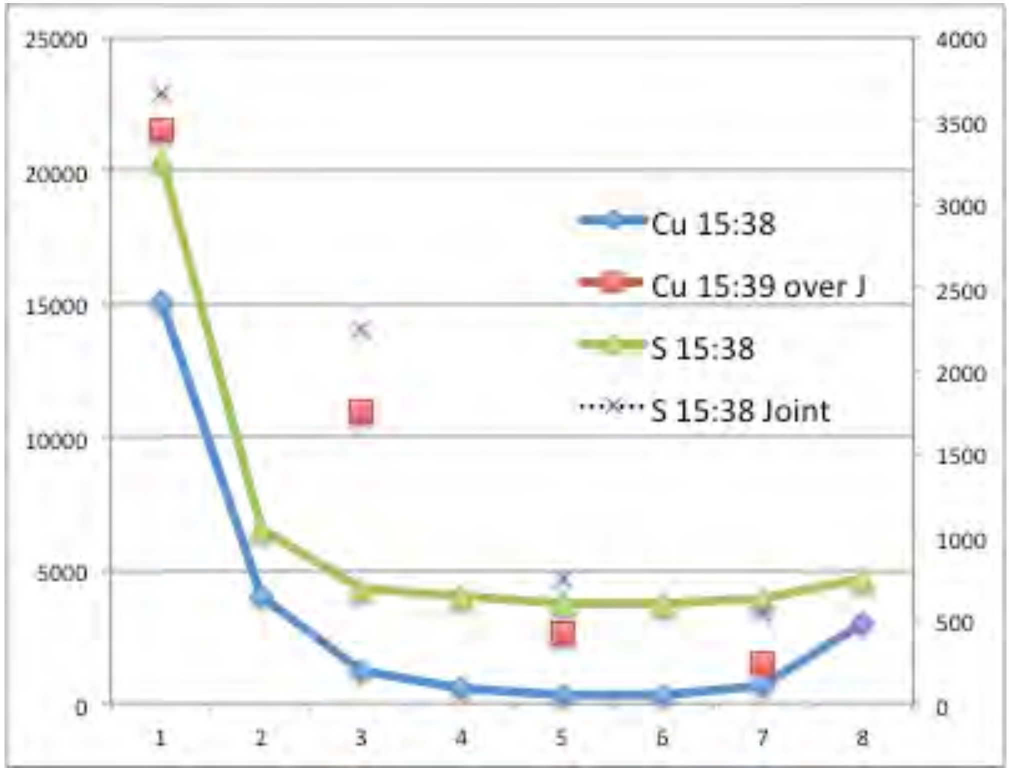






CELLULOSE INVESTIGATION.
LAYER BY LAYER…





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CONCLUSION 1.

- *The Flash-Over was a Consequence of* ***VERY Local Di-Electric Collapse*** *that had taken many Years to develop.*

- *The Driving Force was physical/chemical reactions appearing under influence of Bad Joint Geometry, Bad Chemistry and High Electrical Tension causing e.g. copper emission and very slow formation of X-wax etc.*

CONCLUSIONS 2.

- The process is slow (a failure ***may*** never appear during life time).
- The problem cannot be measured by electrical means.
- There was no butt weld method instructions *or* QA was out of function at time of manufacture.
- 3 different methods distinguished!! 3 shifts?

CORROSIVE SULFUR ATTACK ACCORDING TO A CIGRÉ REPORT.

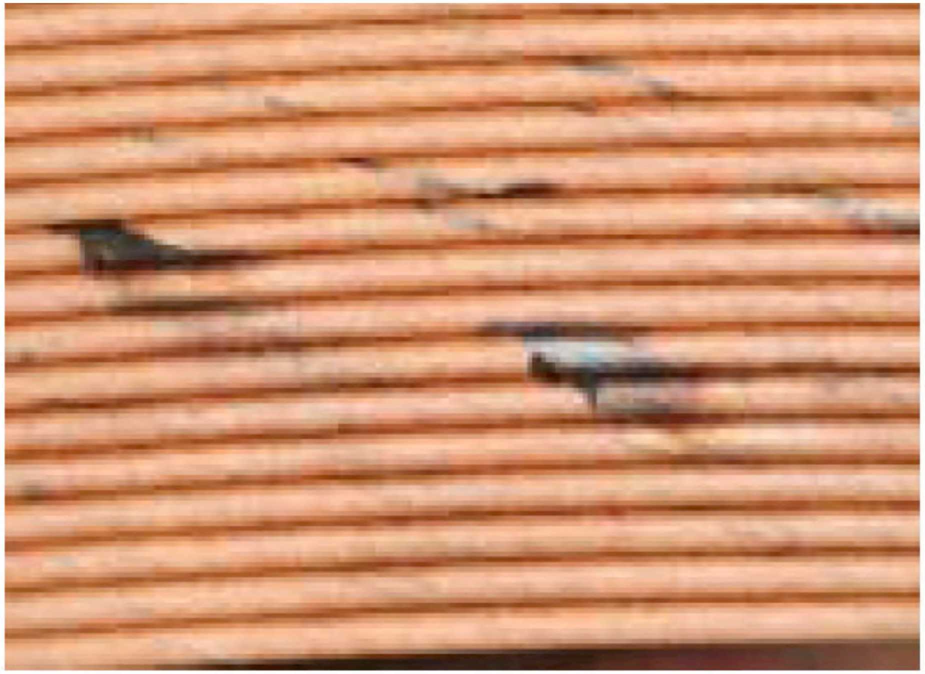

Fig. 1 Example of copper sulphide growing through several layers of covering paper.

Picture and text from a paper published in ELECTRA Feb 2006 by Cigré Task Force A2-31

ENORMOUS NUMBER of publications on Corrosive Sulfur.

Few if ANY FAILURE Reports/ Investigations where the ROOT Cause have actually been identified.

CONCLUSIONS 3.

1. This was **NOT** a CORROSIVE SULFUR failure! despite fulfilling all requirements i.e.
   - DBDS in oil.
   - Failure Mode: Winding turn to winding turn flash-over.
   - At inspection, corrosive attacks were found.
2. Sulphidation Corrosion becomes a problem **ONLY** when **JOINTS ARE BAD**.
3. Real Failure Reason is Defective Joint Geometry causing the start of electro-physical/chemical processes that destroy the insulation system **very locally**. X-wax is formed.

PROVIDED ANSWERS.

- The RANDOMNESS of ”Corrosive Sulphur” failures is explained .
- The Inability to find the **TRUE ROOT** Cause is explained.
- Why Three Phases are often replaced when One has Failed.
- Why no Hydrogen is found despite X-wax formation.
- Why there has been no open publications on the TRUE failure cause